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NA62 present status

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Summary. — NA62 is a fixed-target experiment located in the CERN experimental North Area. The beam is provided by SPS. During the first phase (2007 $\rightarrow$ 2010) the collaboration measured the ratio $R_K = \mathrm{BR}(K \rightarrow e\nu)/\mathrm{BR}(K \rightarrow \mu\nu)$. This measurement is sensitive to Standard Model (SM) deviations; in particular it can test lepton universality. During the second phase, the collaboration aims to measure $\mathrm{BR}(K^+ \rightarrow \pi^+\nu\bar{\nu})$. Due to the sensitivity of this BR to new physics, this decay has a strategic role in the search for physics beyond the SM. The hadronic contribution to the uncertainty is small and the SM prediction is precise: $(8.5 \pm 0.7)10^{-11}$. The apparatus is under construction and the first run is expected for spring 2013. The detector status, prototype tests, and signal sensitivity compared with background rejection will be discussed.

PACS `11.30.Hv` – Flavor symmetries.
PACS `12.15.Hh` – Determination of Cabibbo-Kobayashi & Maskawa (CKM) matrix elements.
PACS `13.20.Eb` – Decays of K mesons.

1. – The physics case

In the search for new physics (NP) effects beyond the Standard Model (SM), flavor-changing neutral-current processes are particurarly relevant. These processes are dominated by penguin and box diagrams and can sensitively test various NP scenarios. Kaons rare and ultra-rare decays, such as $K_L \rightarrow \pi^0 l^+ l^-$ and $K \rightarrow \pi\nu\overline{\nu}$, are particularly clean since no long-distance contributions from processes with intermediate photons are involved and hadronic matrix elements can be obtained from branching ratios (BR) of leading K decays, such as $K \rightarrow \pi e\nu$, via weak isospin rotation [1-4]. In the SM, the theoretical expectation for the charged mode [5], $\mathrm{BR}(K^+ \rightarrow \pi^+\nu\overline{\nu}) = (8.5 \pm 0.7) \times 10^{-11}$, has a 7% non-parametric error. In contrast, possible NP contributions could change the BR by up to a factor of three in many scenarios [6]. The decay $K \rightarrow \pi\nu\overline{\nu}$ may be sensitive to new physics in a wide range even in the absence of a signature of new particles within LHC reach. At present, seven $K^+ \rightarrow \pi^+\nu\overline{\nu}$ events have been identified by the

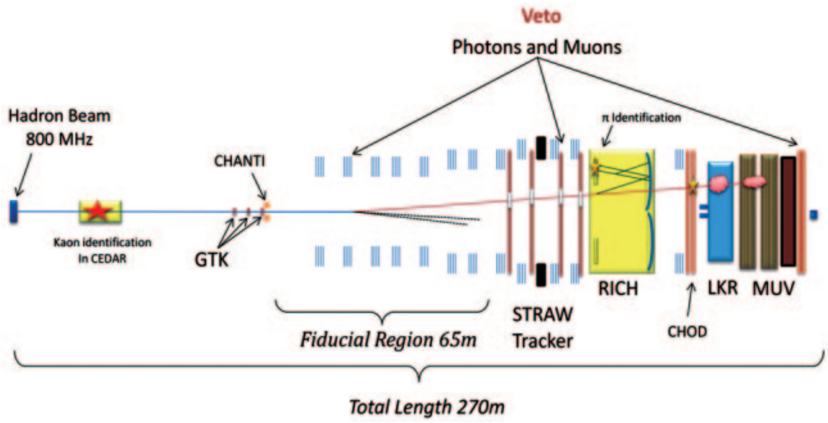

Fig. 1. – Schematic view of the NA62 detector.

BNL E949/E787 stopped-kaon decay experiments [7]. The measured BR is compatible with the SM prediction, although with a large uncertainty: BR $= (1.73^{+1.15}_{-1.05}) \times 10^{-10}$. There is still plenty of room for possible NP effects [8].

2. – The NA62 experimental technique

The aim of the NA62 experiment [9] is to detect about 100 $K^+ \to \pi^+ \nu\bar{\nu}$ events with a $\mathcal{O}(\sim 10\%)$ signal acceptance and a background on the order of 10% in two years of data-taking. The design is inspired by years of experience with the NA48 apparatus and infrastructure. For NA62, the K12 beamline at the CERN SPS North Area will be upgraded to increase the intensity by a factor of 50. In the final setup, a 400 GeV SPS primary proton beam interacts into a beryllium target and produces an unseparated 75 GeV, 800 MHz beam with $\sim 6\%$ K^+, corresponding to ~ 5 MHz kaon decays in a 60 m long fiducial volume. A transverse schematic view of the NA62 detector is shown in fig. 1.

The guiding principles in the experiment design follow from the need to sustain a high-rate environment while guaranteeing high-resolution timing. Kaons are identifiedy by a CEDAR detector upstream to all other detectors.

The goal is to identify a signal BR of $\sim 10^{-10}$ with a total background rejection of the order of 10^{12} against the leading K^+ decay modes.

Both kinematical and PID background rejection are implemented.

Two- and three-body decay modes will be reduced by a factor of $\sim 10^4$ by cutting on the squared missing mass of reconstructed candidates. For this purpose, a fast up-stream tracker of every particle in the beam, the so-called Gigatracker (see subsect. **2**˙1), is used to measure incoming K momentum. Downstream of a 60 m long fiducial region for K decays, a straw-chamber magnetic spectrometer is used to measure with high-resolution daughter particle momenta.

Further rejection of $K_{\mu 2,3,4}$ and $K_{e2,3,4}$ background will be obtained with a ring-imaging Cherenkov counter (see subsect. **2**˙2), used to identify in a efficient and non-destructive way daughter pions and separate them from muons and electrons. The π/μ separation is critical to achieve sufficient rejection for $K_{\mu 2}$ decays. For this purpose, additional information will be provided by a sampling calorimeter, the so-called MUon Veto (MUV), placed after the $27X_0$'s of the existing LKr NA48 electromagnetic calorimeter.

Rejection of modes with π^0's and/or radiative photons will be provided by a hermetic, high-efficiency photon-veto system, covering from 0–50 mrad γ emission angles (see subsect. **2**˙3.1). This has to provide a rejection factor of 10^8 against $K^+ \to \pi^+\pi^0$.

Finally a series of guard rings are placed just after the 3th GTK station (see subsect. **2**˙1) in order to detect inelatic events that can produce a π^+ and so mimic signal events.

A detailed description of the NA62 apparatus can be found in [9].

In the following the main components of the detector and their contributions to the measurement will be described.

2˙1. *Fast Beam Particle Tracking.* – The GigaTracKer(GTK) [10] will measure the 3-momentum of each particle of the 800 MHz beam with precision much better than that given by the momentum bite of the beam. It will also provide a time measurement for single particles. This system is placed upstream, just before the decay volume. Three silicon micro-pixel stations (called GTK1-2-3) with a total thickness of less than 0.5% X_0 each, will provide position measurement while particles traverse a magnetic achromat. A total of 18000, $300 \times 300 \mu\text{m}^2$ pixels for a sensitive area of $60 \times 27\,\text{mm}^2$ will provide spatial hit resolution of $\sim 100\,\mu$m. Momentum will be measured with a fractional error of $\sim 0.2\%$, corresponding to 150 MeV resolution, while direction will be determined with 12 μrad angular resolution. In order not to cause station-by-station hit mismatch in more than 1% of the cases, a hit time resolution better than 200 ps is required. The readout has to sustain rates of up to 150 kHz. The R&D is almost completed, with two read out prototypes developed and compared, both with FE circuits in 130 nm IBM CMOS technology.

There is a drawback in this technological choise. In fact nuclear inelastic interaction at the last GTK station can produce pions or other particles that, if emitted at low angle, can reach the STRAW tracker and mimic a signal decay, if no other track is detected. A detector called CHANTI (CHarged ANTIcounter) is intended to identify inelastic interactions in the GTK by tagging particles at higher angles with respect to the beam.

2˙2. *PID of decay products.* – A RIng-imaging CHerenkov counter (RICH) [11], will provide rejection for muons with less than 0.5% mis-ID probability for events not identified by the MUV. More than three standard deviations of π/μ separation should be achieved in the $K \to \pi\nu\overline{\nu}$ pion momentum range, $15 < p_\pi < 35\,\text{GeV}$. Time determination with a resolution better than 100 ps should be guaranteed, to efficiently match with Gigatracker information. This performance will be obtained by using a 17 m long, 3 m diameter tank, filled with 1 atm Ne gas acting as radiator. Mirrors at the downstream side of the volume will focus rings of Cherenkov light into two separated regions on the upstream side. These are instrumented with 2000 photomultiplier tubes (PMT's), each 18 mm wide.

In a dedicated test beam for a prototype with ~ 400 PMT's a muon rejection better than 1% has been measured, with an overall pion loss of few per mil and a time resolution better than 100 ps, these figures holding across the momentum range of interest.

2˙3. *Efficient photon veto.* – A system of different detectors will veto photons providing a rejection of 10^8 for π^0 from K^+ decay in a 60 m long fiducial volume, allowing the background from $K^+ \to \pi^+\pi^0$ decays to be reduced to less than one part in 10^{12}. Photons emitted at very small angle, $< \sim 1\,\text{mrad}$, will be detected by compact calorimeters in the

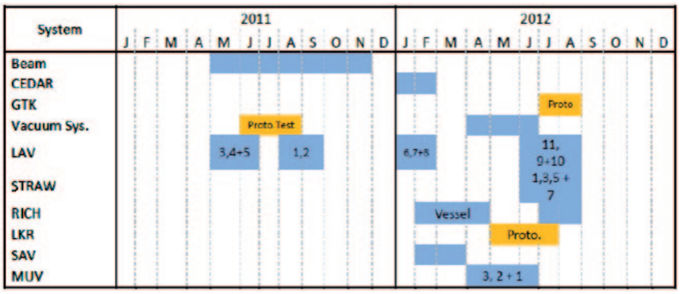

Fig. 2. – NA62 schedule up to 2012.

forward direction, with a required inefficiency of $< 10^{-6}$ above 6 GeV. In the angular range between 1 mrad and 8 mrad, the existing NA48 LKr calorimeter will be re-used, profiting of a measured inefficiency $< 10^{-5}$ for photons above 6 GeV. At large angle, between 8 mrad and 50 mrad, a new system so-called Large Angle Veto (LAV) will provide γ detection with an inefficiency $<\sim 10^{-4}$ above O(100 MeV).

2˙3.1. The LAV system. After an intense R&D activity [12], the re-use of SF57 lead glass blocks from the dismounted OPAL barrel electromagnetic calorimeter, already instrumented with R-2238 Hamamatsu phototubes, has been validated. The inefficiency measured with dedicated test beams satisfies the requirements and is comparable with other alternatives, including lead/scintillating-fiber or lead/scintillating-tile sampling calorimeters. The LAV will be made of 12 stations of increasing diameter. Each station will be composed of four or five layers (depending on station position), for a total depth of 29 to 37 X_0's. Layers are staggered to guarantee that incident particles must encounter at least three blocks, corresponding to more than $20X_0$'s. A total of ~ 2500 blocks will be used. Since high sensitivity to photons in the range from $O(100)$ MeV to 20 GeV is required, the front-end electronics must guarantee a wide dynamic range from 20 mV (tipical MIP signal) up to 10 V on a 50 Ω load. A simple and cost-effective solution, easy to scale and to integrate with a common NA62 trigger and data acquisition infrastructure has been adopted: a time-over-threshold discriminator, with two adjustable thresholds. Signals will be clamped, split into two, amplified, and discriminated with two thresholds to allow slewing corrections. The LVDS digital output will allow accurate leading and trailing edge time determinations. From the time-over-threshold, a 10% resolution measurement of the charge will be made, allowing the LAV system to operate as a calorimeter as well as a veto. Test beam results show that a fractional energy resolution $\sim 10\%E\,(\mathrm{GeV})^{-1/2}$ and a time resolution $\sim 300\,\mathrm{ps}E(\mathrm{GeV})^{-1/2}$ are achievable.

3. – Experiment status

The experiment was presented to the CERN SPS Committee in 2005 and, after a long R&D program on the different sub-detectors, it was approved by the CERN Research Board in December 2008. Multiple test beam have been performed for advanced prototypes or parts of single sub-detectors, as discussed above. Commissioning is on going and a technical run is planned for the end of 2012 when the apparatus will be almost complete (see fig. 2), GTK will not partecipate, and only 2 out of 4 STRAW plane will be ready. The first physics run is expected to take place in late 2013.

REFERENCES

[1] Buras A. J., Gorbahn M., Haisch U. and Nierste U., *Phys. Rev. Lett.*, **95** (2005) 261805; *J. High Energy Phys.*, **11** (2006) 002.
[2] Isidori G., Mescia F. and Smith C., *Nucl. Phys. B*, **718** (2005) 319.
[3] Buchalla G., D'Ambrosio G. and Isidori G., *Nucl. Phys. B*, **672** (2003) 387.
[4] Mescia F. and Smith C., ArXiv:0705.2025 [hep-ph], update for *Phys. Rev. D*, **76** (2007) 034017.
[5] Brod J., Gorbahn M. and Stamou E., arXiv:1009.0947 [hep-ph], and references therein.
[6] Isidori G., Mescia F., Paradisi P., Smith C. and Trine S., *JHEP*, **0608** (2006) 064 [hep-ph/0604074].
[7] Artamonov A. V. *et al.* (BNL-E949 Collaboration), *Phys. Rev. D*, **79** (2009) 092004, arXiv:0903.0030 [hep-ex].
[8] From the FlaviaNet Kaon working group, `http://www.lnf.infn.it/wg/vus/content/Krare_BSM_new.eps`.
[9] NA62 Collaboration, CERN NA62 note, NA62-10-07 `http://na62.web.cern.ch/NA62/Documents/NotesDoc/na62-07-10.pdf`.
[10] Mazza G., Ceccucci A., Cortina E. *et al.*, *Nucl. Instrum. Methods A*, **617** (2010) 558.
[11] Bucci F., Collazuol G. and Sergi A., *Nucl. Instrum. Meth. A*, **623** (2010) 327.
[12] Antonelli A. *et al.*, *J. Phys. Conf. Ser.*, **160** (2009) 012020 (*Nucl. Phys. Proc. Suppl.*, **197** (2009) 224).